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## XVI.

*Discussion of Observations for the Isodynamic, Isogonic, and Isoclinal Curves of Terrestrial Magnetism on and near the Line of the Boundary Survey between the United States and Mexico, made in 1849, 1850, 1851, and 1852, under the Orders of*

W. H. EMORY,

ASTRONOMER OF THE BOUNDARY COMMISSION,

*And combined with Observations at San Francisco (California), and Dollar Point (East Base), and Jupiter (Texas), furnished by*

A. D. BACHE,

SUPERINTENDENT OF THE UNITED STATES COAST SURVEY.

*With a Map.*

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*(Communicated to the Academy, February 13th, 1855, by W. C. Bond, Director of the Observatory of Harvard College.)*

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THE magnetic elements contained in this paper have been obtained with a Fox Dip-Circle, — the same which was used by Major Emory for the observations published in Volume V. of the Memoirs of the Academy.

The values of total intensity are expressed in units of the intensity at Falmouth, England. To reduce them to the arbitrary standard commonly adopted, they should be multiplied by the coefficient 1.374. As observations of this element with Mr. Fox's apparatus are liable to be affected by changes in the magnetic condition of the needles, it would be desirable to know to what extent such changes may have taken place. The successive comparisons, between 1844 and 1854, which have been made at Cambridge, with the instrument used by Major Emory, furnish the data for estimating their amount. If it be allowable to assume that there has been no sensible secular change of total intensity at Cambridge since 1842, at which time its value by direct

determination was 1.777 in units of the common scale, there would be a correction of  $+ 0.002 \times 1.374$  to be applied yearly, for the interval elapsed since 1844, to the intensity derived from this instrument by using the weights, and of  $- 0.005 \times 1.374$ , when the deflectors are employed.

In the manuscript copy of the observations received from Major Emory, the particulars respecting the manner of making the observations have not been given. It can only be assumed that the mean of the above corrections,  $= - 0.0015 \times 1.374 \times (1851 - 1844) = - 0.014$ , is to be applied to all the total intensities, (reduced to the common scale,) contained in the present paper.

In projecting the lines of equal variation, dip, and total intensity, as represented upon the accompanying map, no attempt has been made to consider the *curvature* of the lines. A complete determination of this element will best be made by combining the results here presented with others from points lying at some distance from the line of the survey.

The accompanying tables contain the principal steps of the reductions furnished by Major Emory, agreeably to the following formula. In constructing the lines upon the map, however, a different combination has been employed.

### FORMULÆ

*for computing, theoretically, the Variations in the Magnetic Declination, Intensity, or Dip, due to Changes in the Latitude and Longitude.*

[From the Fifth Report of the British Association for the Advancement of Science, 1835.]

$$\begin{aligned} x \sum d L^2 + y \sum d L \cdot d M &= \sum d L \cdot d [V, I \text{ or } D] \\ x \sum d L \cdot d M + y \sum d M^2 &= \sum d M \cdot d [V, I \text{ or } D], \end{aligned}$$

in which

$x$  = variation of the magnetic element in Latitude.

$y$  = " " " " in Longitude.

$d L$  = difference of Latitude, from the origin.

$d M$  = " Longitude, "

$d V$  = " Declination, "

$d I$  = " Intensity, "

$d D$  = " Dip, "

$\frac{x}{y}$  = tang.  $Z$ ;  $Z$  being the angle made with the meridian by the line passing through all the points of equal declination, intensity, or dip.

*Isodynamic Observations.*

Station.	Date.	Inst.	Weight.	Intensity.	Latitude.	Longitude.
Panama, . . .	April 2, 1849,	Fox Dip,	2 grains,	0.87766	N. 8 57 12.15	W. 79 29 24.5
" " "	" " "	" 3	" "	0.87573		
San Francisco, .	Mar. 12, 1852,	" 2	" "	1.1712	37 46 53	122 27 30
" " "	" " "	" 3	" "	1.1563		
Sta. Maria, . .	Sept. 15, 1849,	" 2	" "	1.1490		
" " "	" " "	" 3	" "	1.1635		
Colorado Desert,	Dec. 22, 1851,	" 2	" "	1.1284	32 43 43	114 36 45
" " "	" " "	" 3	" "	1.1244		
Rio Gila, near Junc-	Dec. 16, 1851,	" 2	" "	1.1367	32 43 32.3	114 32 51.6
tion of Colorado,	Dec. 9, 1851,	" 2	" "	1.1457	32 59 49.1	112 36 58.2
Station 38, . .	" " "	" 3	" "	1.1384		
" " "	" " "	" 2	" "	1.1528	33 10 14.7	111 54 13.6
Station 31, . .	Nov. 22, 1851,	" 3	" "	1.1486		
" " "	" " "	" 2	" "	1.1409	33 9 4.4	110 44 25.6
Pimo Villages, .	Nov. 20, 1851,	" 3	" "	1.1452		
" " "	" " "	" 2	" "	1.1467	32 59 6.8	110 39 34.8
San Pedro, . .	Sept. 9, 1851,	" 3	" "	1.1411		
" " "	" " "	" 2	" "	1.1686	32 47 53.1	108 4 26.2
Copper Mines, .	Aug. 18, 1851,	" 3	" "	1.1592		
" " "	" " "	" 2	" "	1.1747	32 22 0	106 47 34.8
Doña Ana, . . .	Aug. 23, 1851,					

(No. 1.)

Station.	L.	M.	I.	d L.	d M.	d I.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d I.	d M. d I.
San Francisco,	37 46	122 27	1.163	+3 56	-6 15	+0.019	+55696	+140625	- 88500	+4.484	-7.125
Sta. Maria,	33 2	116 51	1.156	-0 48	-0 39	+0.012	+ 2304	+ 1521	+ 1872	-0.576	-0.468
Colorado Des't,	32 43	114 36	1.126	-1 7	+1 36	-0.018	+ 4489	+ 9216	- 6432	+1.206	-1.728
Near Mouth of											
Gila,	32 43	114 33	1.136	-1 7	+1 39	-0.008	+ 4489	+ 9801	- 6633	+0.536	-0.792
Station 38,	32 59	112 36	1.141	-0 51	+3 36	-0.003	+ 2601	+ 46656	- 11016	+0.153	-0.648
	33 51	116 12	1.144				+69579	+207819	-110709	+5.803	-10.761

(No. 2.)

Station.	L.	M.	I.	d L.	d M.	d I.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d I.	d M. d I.
Station 31,	33 10	111 54	1.150	+17	-2 5	-0.005	+ 289	+12625	- 2125	-0.085	+0.625
Pimo Villages,	33 7	111 44	1.143	+14	-1 55	-0.012	+ 196	+30625	- 2450	-0.168	+1.380
Rio San Pedro,	32 59	110 39	1.143	+ 6	-0 50	-0.012	+ 36	+ 2500	- 300	-0.072	+0.600
Copper Mines,	32 47	108 41	1.164	- 6	+1 45	+0.009	+ 36	+11025	- 630	-0.054	+0.945
Doña Ana,	32 22	106 47	1.174	-31	+3 2	+0.019	+ 961	+33124	- 5642	-0.589	+3.458
	32 53	109 49	1.155		3	1	+1518	+92899	-11147	-0.968	+7.008

*Isoclinal Observations.*

(No. 1.)

Station.	L.	M.	Inc.	d L.	d M.	d D.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d D.	d M. d D.
S. Francisco,	37° 46' 122° 27' 62° 32' +3° 0' -4° 2' +2° 15' +	32400 +	58564 -	43560 +	24200 -	32670					
Sacramento,	38° 34' 121° 17' 64° 3' +3° 48' -2° 52' +3° 46' +	51984 +	29584 -	39216 +	51528 -	38672					
San Diego,	32° 42' 117° 8' 57° 33' -2° 4' +1° 17' -2° 44' +	15376 +	5929 -	9548 +	20336 -	12628					
S. Isabella,	33° 8' 116° 41' 58° 48' -1° 38' +1° 44' -1° 29' +	9604 +	10816 -	10192 +	8722 -	9256					
Mouth of Rio Gila,	32° 43' 114° 33' 58° 30' -2° 3' +3° 52' -1° 47' +	15129 +	53824 -	28546 +	13161 -	24824					
	34° 46' 118° 25' 60° 17' 3' 1' 1' +	124493 +	158717 -	131062 +	117947 -	118050					

$$x = 1.257 \log. = 0.099335$$

$$y = 0.295 \text{ " } = \overline{1.469822}$$

$$\text{tang } Z = 0.629513 \text{ } Z = 76^\circ 47'$$

(No. 2.)

Station.	L.	M.	Inc.	d L.	d M.	d D.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d D.	d M. d D.
XLV.	32° 41' 114° 5' 58° 24' -10° -33° -30° +100° +1089° +330° +300° +990°										
XLIV.	32° 44' 113° 50' 58° 30' -7° -18° -24° +49° +324° +126° +168° +432°										
XLIII.	32° 49' 113° 33' 58° 43' -2° -1° -11° +4° +1° +2° +22° +11°										
XLII.	32° 59' 113° 11' 59° 16' +8° +21° +22° +64° +441° +168° +176° +462°										
XLI.	33° 1' 113° 2' 59° 36' +10° +30° +42° +100° +900° +300° +420° +1260°										
	32° 51' 113° 32' 58° 54' 1' 1' 1' +	317 +	2755 +	926 +	1086 +	3155 +					

$$x = 2.426 \log. = 0.384353$$

$$y = -0.343 \text{ " } = \overline{1.535294}$$

$$\text{tang } Z = 0.749059 \text{ } Z = 79^\circ 53'$$

(No. 3.)

Station.	L.	M.	Inc.	d L.	d M.	d D.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d D.	d M. d D.
XL.	33° 2' 112° 51' 59° 15' -2° -27° +6° +4° +729° +54° -12° -162°										
XXXIX.	32° 59' 112° 42' 58° 49' -5° -18° -20° +25° +324° +90° +100° +360°										
XXXVIII.	33° 0' 112° 37' 58° 53' -4° -13° -16° +16° +169° +52° +64° +208°										
XXXII.	33° 9' 111° 57' 59° 22' +5° +27° +13° +25° +729° +135° +65° +351°										
XXXI.	33° 10' 111° 54' 59° 28' +6° +30° +19° +36° +900° +180° +114° +570°										
	33° 4' 112° 24' 59° 9' 1' 1' 1' +										

$$x = 1.265 \log. = 0.102091$$

$$y = 0.418 \text{ " } = \overline{1.621176}$$

$$\text{tang } Z = 0.480915 \text{ } Z = 74^\circ 42'$$

(No. 4.)

Station.	<i>L.</i>	<i>M.</i>	Inc.	<i>d L.</i>	<i>d M.</i>	<i>d D.</i>	<i>d L</i> <sup>2</sup> .	<i>d M</i> <sup>2</sup> .	<i>d L. d M.</i>	<i>d L. d D.</i>	<i>d M. d D.</i>
XXX.	33 7	111 44	59 6	+4	-21	-8	+16	+441	-84	-32	+168
XXIX.	33 3	111 33	59 6	0	-10	-8		+100			+80
XXVIII.	33 0	111 23	59 16	-3	0	+2	+9			-6	
XXVII.	33 2	111 16	59 19	-1	+7	+5	+1	+49	-7	-5	+35
XXVI.	33 4	111 2	59 24	+1	+21	+10	+1	+441	+21	+10	+210
	33 3	111 23	59 14	1	3	1	27	+1031	-70	-33	+493

$$x = 2.424 \log. = 0.384533$$

$$y = 0.478 \quad " = \bar{1}.679428$$

$$\text{tang } Z = 0.705105 \quad Z = 78^\circ 50'$$

(No. 5.)

Station.	<i>L.</i>	<i>M.</i>	Inc.	<i>d L.</i>	<i>d M.</i>	<i>d D.</i>	<i>d L</i> <sup>2</sup> .	<i>d M</i> <sup>2</sup> .	<i>d L. d M.</i>	<i>d L. d D.</i>	<i>d M. d D.</i>
XXIV.	33 6	111 2	59 19	+3	-12	+6	+9	+144	-36	+18	-72
XXIII.	33 6	110 55	59 23	+3	-5	+10	+9	+25	-15	+30	-50
XXII.	33 5	110 49	59 13	+2	+1	0	+4	+1	+2		
XXI.	33 2	110 46	58 59	-1	+4	-14	+1	+16	-4	+14	-56
XX.	32 59	110 39	59 10	-4	+11	-3	+16	+121	-44	+12	-33
	23 3	110 50	59 13	3	1	1	+39	+307	-97	+74	-211

(No. 6.)

Station.	<i>L.</i>	<i>M.</i>	Inc.	<i>d L.</i>	<i>d M.</i>	<i>d D.</i>	<i>d L</i> <sup>2</sup> .	<i>d M</i> <sup>2</sup> .	<i>d L. d M.</i>	<i>d L. d D.</i>	<i>d M. d D.</i>
XIX.	33 4	110 35	59 4	-4	+1	-20	+16	+1	-4	+80	-20
XVIII.	33 8	110 44	60 8	0	-8	+44		+64			-352
XVII.	33 12	110 42	59 23	+4	-6	-1	+16	+36	-24	-4	+6
XV.	33 9	110 31	59 27	+1	+5	+3	+1	+25	+5	+3	+15
XIII.	33 9	110 28	58 57	+1	+8	-27	+1	+64	+8	-27	-216
	33 8	110 36	59 24				+34	+190	-15	+52	-567

(No. 7.)

Station.	<i>L.</i>	<i>M.</i>	Inc.	<i>d L.</i>	<i>d M.</i>	<i>d D.</i>	<i>d L</i> <sup>2</sup> .	<i>d M</i> <sup>2</sup> .	<i>d L. d M.</i>	<i>d L. d D.</i>	<i>d M. d D.</i>
Santa Vita											
del Cobre,	32 47	108 4	59 17	+36	-1 3	+10	+1296	+3969	-2621	+360	-730
IX. on Line,	32 22	107 24	59 9	+11	-23	+2	+121	+529	-253	+22	-46
Doña Ana,	32 22	106 47	59 6	+11	+14	-1	+121	+196	+154	-11	-14
Frontera,	31 48	106 33	59 5	-23	+28	-2	+529	+784	-664	+46	-56
S. Elciario,	31 35	106 16	58 57	-36	+45	-10	+1296	+2025	-1620	+360	-450
	32 11	107 1	59 7	1	1	1	+3363	+7503	-5004	+777	-1296

(No. 8.)

Station.	L.	M.	Inc.	d L.	d M.	d D.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d D.	d M. d D.
Mouth of Cañon,	31 2	105 37	57 38	+2 51	-4 33	+3 0	+29241	+ 74529	- 46681	+30780	- 49140
Presidio del											
Norte,	29 34	104 25	55 41	+1 23	-3 21	+1 3	+ 6889	+ 40401	- 16683	+ 5229	- 13230
Ft. Duncan,	28 42	100 30	55 31	+0 31	+0 34	+0 53	+ 961	+ 1156	+ 1054	+ 1643	+ 1802
Ft. McIntosh,	27 30	100 55	4 7	-0 41	+0 59	-0 31	+ 1681	+ 3481	- 2419	+ 1271	- 1829
Ringgold Bar-											
racks,	26 23	98 43	52 27	-1 48	+2 21	-2 11	+11664	+ 19881	- 15228	+14148	- 18471
Mouth of Rio											
Grande,	25 57	97 75	2 23	-2 14	+3 57	-2 15	+17956	+ 56169	- 31858	+18090	- 31995
	28 11	101 45	4 38	2	3	1	+68392	+195617	-111815	+71161	-112863

$$x = 1.485 \log. = 0.171726$$

$$y = 0.271 \quad " \quad = 1.432969$$

$$\text{tang } Z = 0.738757 \quad Z = 79^\circ 39'$$

*Isogonic Observations.*

(No. 1.)

Station.	L.	M.	Var. E.	d L.	d M.	d V.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d V.	d M. d V.
San Francisco,	37 46	122 27	15 37	+4 6	-5 50	+2 16	+60516	+122500	+86100	+33456	-47600
San Diego,	32 42	117 12	13 15	-0 58	-0 35	-0 6	+ 3364	+ 1225	+ 2030	+ 348	+ 210
Camp Riley,	32 35	117 5	12 57	-1 5	-0 28	-0 24	+ 4225	+ 784	+ 1820	+ 1560	+ 672
San Isabel,	33 7	116 41	12 34	-0 33	-0 4	-0 47	+ 1089	+ 16	+ 132	+ 1551	+ 188
Mouth of Rio Gila,	32 43	114 33	12 50	-0 57	+2 4	-0 31	+ 3249	+ 15376	+ 7068	+ 1767	+ 3844
Pimo Villages,	33 7	111 44	12 52	-0 33	+4 53	-0 29	+ 1089	+ 85849	- 9669	+ 957	- 9669
Mean,	33 40	116 37	13 21				+73532	+225750	-98855	+39693	-60043

$$x = + 0.442$$

$$y = - 0.072$$

(No. 2.)

Station.	L.	M.	Var. E.	d L.	d M.	d V.	d L <sup>2</sup> .	d M <sup>2</sup> .	d L. d M.	d L. d V.	d M. d V.
Pimo Villages,	33 7	111 44	12 52	+ 70	-217	+57	+ 4900	+ 47089	-15190	+ 3990	-12369
San Pedro,	32 59	110 40	12 25	+ 62	-183	+30	+ 3844	+ 33489	-11346	+ 1860	- 5490
Cobre Mines,	32 47	108 4	11 22	+ 50	- 27	-33	+ 2500	+ 729	- 1350	- 1650	+ 891
Doña Ana,	32 22	106 47	12 7	+ 25	+ 50	+15	+ 625	+ 2500	+ 1250	+ 375	+ 750
Frontera,	31 48	106 33	12 24	- 9	+ 64	+29	+ 81	+ 4096	- 576	- 261	+ 1856
Mouth of Cañon,	31 2	105 37	12 1	- 55	+120	+ 6	+ 3025	+ 14400	- 6600	- 330	+ 720
Pres. del Norte,	29 34	104 24	10 16	-143	+193	-99	+20449	+ 37249	-27599	+14157	-19107
Mean,	31 57	107 37	11 55				+35424	+139552	-61411	+18141	-32749

$$x = + 0.444$$

$$y = - 0.039$$

(No. 3.)

Station.	<i>L.</i>	<i>M.</i>	Var. <i>E.</i>	<i>d L.</i>	<i>d M.</i>	<i>d V.</i>	<i>d L</i> <sup>2</sup> .	<i>d M</i> <sup>2</sup> .	<i>d L. d M.</i>	<i>d L. d V.</i>	<i>d M. d V.</i>
Pres. del Norte,	29 34	104 24	10 16	+117	-254	+34	+13689	+ 64516	-29718	+ 3978	- 8636
Eagle Pass,	28 42	100 30	10 1	+ 65	- 20	+19	+ 4225	+ 400	- 1300	+ 1235	- 380
Ft. McIntosh,	27 30	100 5	10 0	- 7	+ 5	+18	+ 49	+ 25	- 35	- 126	+ 90
Ringgold Bar- racks,	26 23	98 43	9 15	- 74	+ 87	-27	+ 5476	+ 7569	- 6438	+ 1998	- 2349
Mouth of Rio Grande,	25 57	97 7	9 0	-100	+183	-42	+10000	+ 33489	-18300	+ 4200	- 7686
Mean,	27 37	100 10	9 42				+33439	+105999	-55791	+11285	-18961

$$x = + 0.317$$

$$y = - 0.012$$

(No. 4.)

Station.	<i>L.</i>	<i>M.</i>	Var. <i>E.</i>	<i>d L.</i>	<i>d M.</i>	<i>d V.</i>	<i>d L</i> <sup>2</sup> .	<i>d M</i> <sup>2</sup> .	<i>d L. d M.</i>	<i>d L. d V.</i>	<i>d M. d V.</i>
Ft. McIntosh,	27 30	100 5	10 0	- 24	-194.5	+46	+ 576	+37830	+ 4668	-1104	- 8947
Ringgold Bar- racks,	26 23	98 43	9 15	- 91	-112.5	+ 1	+ 8281	+12656	+10237	- 91	- 112
Mouth of Rio Grande,	25 57	97 7	9 0	-117	- 16.5	-14	-13689	+ 272	+ 1930	+1638	+ 231
Dollar Point,	29 26	94 53	8 57	+ 92	+117.5	-17	+ 8464	+13806	+10810	-1564	- 1997
East Base,	29 13	94 55	9 5	+ 79	+115.5	- 9	+ 6241	+13340	+ 9124	- 711	- 1039
Jupiter,	28 55	95 20	9 9	+ 61	+ 90.5	- 5	+ 3721	+ 8190	+ 5520	- 305	- 452
Mean,	27 54	96 50	59 14				+40972	+86094	+42289	-2137	-12316

$$x = + 0.193$$

$$y = - 0.283$$



